



KOREAN INDUSTRIAL PROPERTY OFFICE

This is to certify that the following application annexed hereto is a true copy from the records of the Korean Industrial Property Office.

Application Number: Patent Application No. 99-28449

Date of Application: July 14, 1999

Applicant(s): Samsung Electronics Co., Ltd. (LCD Business)

COMMISSIONER

(Translation)

**APPLICATION FOR PATENT**

**APPLICANT:** Samsung Electronics Co., Ltd. (LCD Business)  
416, Maetan-dong, Paldal-ku, Suwon-city,  
Kyungki-do, Korea

**ATTORNEYS:** Won-Ho KIM, Won-Kun KIM

**INVENTORS :** 1) KWAG, Jin-Oh  
Taeyoung Apt. 933-1201, Byeokjeok-gol,  
Youngtong-dong, 969-1, Paldal-ku, Suwon-  
city, Kyungki-do, Korea  
2) KIM, Sang-Soo  
Maetan 3-dong 416, Paldal-ku, Suwon-city,  
Kyungki-do, Korea

**TITLE OF INVENTION:** LIQUID CRYSTAL DISPLAY

Submitted herewith is/are an application identified above pursuant to  
Article 42 of the Patent Act.

This 14<sup>th</sup> day of July, 1999

Patent Attorneys: Won-Ho KIM  
Won-Kun KIM

To the Commissioner of  
the Korean Industrial Property Office

Attachment: 1. Abstract, specification (and drawing) - one copy each



## **[ABSTRACT OF THE DISCLOSURE]**

### **[ABSTRACT]**

A plurality of triangle column shaped protrusion are formed on a lower substrate. The protrusions make at least one pair and is formed of insulating layers and a semiconductor layer forming TFTs. Pixel electrodes are formed on the protrusions made of ITO (indium tin oxide) or IZO (indium zinc oxide). The pixel electrodes have opening patterns and the opening patterns expose one of the paired protrusions. An alignment layer is formed on the pixel electrodes. An upper substrate having a common electrode and an alignment layer faces the lower substrate. A liquid crystal layer having negative dielectric anisotropy is disposed between the upper and lower substrates. When a voltage difference is applied between the two electrodes, domains distinguished by their liquid crystal alignment are formed by the opening patterns and the protrusions.

### **[REPRESENTATIVE FIGURE]**

Fig. 4

### **[KEY WORDS]**

vertical alignment, domain division, opening pattern, protrusion, fringe field

**[SPECIFICATION]**

**[TITLE OF THE INVENTION]**

Liquid Crystal Display

**[BRIEF DESCRIPTION OF THE DRAWINGS]**

Figs. 1A and 1B are cross sectional views of a liquid crystal display according to a prior art, illustrating the orientation states of liquid crystal molecules when voltage application is absent and present, respectively;

Figs. 2A and 2B are cross sectional views of a liquid crystal display according to another prior art, illustrating the orientation states of liquid crystal molecules when voltage application is absent and present, respectively

Fig. 3 is a cross sectional view of a liquid crystal display according to a preferred embodiment of the present invention, illustrating the orientation states of liquid crystal molecules when voltage application is absent;

Fig. 4 is a cross sectional view of the liquid crystal display shown in Fig. 3, illustrating the orientation states of the electric fields and liquid crystal molecules with the voltage applied;

**[DETAILED DESCRIPTION OF THE INVENTION]**

**[OBJECT OF THE INVENTION]**

**[FIELD OF THE INVENTION AND CONVENTIONAL ART IN THE FIELD]**

The present invention relates to a liquid crystal display and, more particularly, to a vertical alignment liquid crystal display which has a structure capable of dividing a pixel area into multiple domains with different orientation directions of liquid crystal molecules.

Generally, liquid crystal displays have a structure where a liquid crystal is sandwiched between two substrates, and an electric field is applied to the liquid crystal to control the amount of light transmission.

In the usual twisted nematic (TN) liquid crystal displays, the liquid crystal molecules injected into the gap between the two substrates are oriented parallel to the substrates, and spirally twisted with a predetermined pitch. The long axis (usually called the "director") of the liquid crystal molecules continuously varies in orientation direction, and the viewing angle characteristics depend upon such orientation directions of the liquid crystal molecules.

However, in the TN liquid crystal display, light is not completely blocked at an off state in the normally black mode so that a poor contrast ratio results. The contrast ratio is altered depending upon the viewing angle, and there is a half tone of brightness difference depending on the viewing angle so that stable picture images cannot be obtained. Furthermore, the picture qualities at side edge portions of the screen are not symmetrical to each other with respect to the middle portion. These all result in poor viewing angle characteristics.

However, the vertical alignment liquid crystal displays where the liquid crystal

molecules are vertically aligned in the absence of a voltage but twisted in various directions with the voltage applied exhibit excellence in various aspects, such as contrast ratio and response speed compared to the TN liquid crystal displays. Furthermore, when a compensation film is used to divide the twisting of the liquid crystal molecules in various predetermined directions, a wide viewing angle can be effectively obtained.

Recently, a technique for forming an alignment control member such as a pyramid-shaped protrusion on the substrates, a technique for forming an opening pattern at the transparent electrodes, and a technique for forming a protrusion pattern on one of the substrates while forming an opening pattern at the other substrate have been proposed as methods to control the orientation directions of the liquid crystal molecules. The protrusion or opening pattern is designed to achieve four domain divisions in the orientation direction of the liquid crystal molecules at which the efficiency of light usage becomes highest.

Figs. 1A and 1B are cross sectional views of a liquid crystal display according to a prior art where the orientation states of liquid crystal molecules are illustrated in the absence and presence of the voltage application.

As shown in the drawings, a transparent pixel electrode 11 is formed at a bottom substrate 10, and a first opening portion 1 is formed at the pixel electrode 11. A top substrate 20 facing the bottom substrate 10 is provided with a transparent common electrode 21. A second opening portion 2 is formed at the common electrode 21. The bottom and top substrates 10 and 20 are arranged such that the first opening portion 1 is displaced with respect to the second opening portion 2. Negative dielectric

anisotropy liquid crystal molecules 30 are injected into the gap between the bottom and top substrates 10 and 20.

As shown in Fig. 1A, the liquid crystal molecules 30 are oriented perpendicular to the substrates 10 and 20 in the absence of the voltage application.

As shown in Fig. 1B, when voltage is applied to the pixel electrode 11 and the common electrode 21, most of the regions at the pixel area are under the influence of an electric field normal to the substrates 10 and 20, but the regions adjacent to the opening portions 1 and 2 are under a fringe field beginning from the edges of the opening portions 1 and 2 and focused onto the common electrode 21 and the pixel electrode 11, respectively. As the negative dielectric anisotropy liquid crystal molecules 30 are inclined to orient in a direction normal to that of the electric field, the long axes of the liquid crystal molecules adjacent to the opening portions 1 and 2 are twisted while being tilted with respect to the substrates 10 and 20. In this case, two side regions of either of the opening portions 1 and 2 where the orienting directions of the liquid crystal molecules 30 are opposite to each other are present so that the optical characteristics of the two side regions are compensated, resulting in a wide viewing angle.

Figs. 2A and 2B are cross sectional views of a liquid crystal display according to another prior art where the orientation states of liquid crystal molecules are illustrated in the absence and presence of voltage application.

As shown in Figs. 2A and 2B, a pixel electrode 12 based on a transparent conductive material such as indium tin oxide is formed at a bottom substrate 10, and a pyramid-shaped first protrusion 13 and a vertical alignment film (not shown) are

sequentially formed on the pixel electrode 12. A transparent common electrode 22 is formed at a top substrate 20, and a second pyramid-shaped protrusion 23 and a vertical alignment film (not shown) are sequentially formed at the common electrode 22. Negative dielectric anisotropy liquid crystal molecules 30 are injected into the gap between the vertical alignment films of the bottom and top substrates 10 and 20.

As shown in Fig. 2A, in the absence of voltage application, most of the liquid crystal molecules 30 are oriented perpendicular to the vertical alignment films, but the liquid crystal molecules 30 positioned close to the protrusions 13 and 23 are tilted with respect to the vertical alignment films at predetermined angles.

As shown in Fig. 2B, when voltage is applied to the pixel and common electrodes 12 and 22, the liquid crystal molecules are twisted in a direction parallel to the substrates 10 and 20. As the liquid crystal molecules 30 positioned close to the protrusion 13 are tilted in the opposite directions with respect to the region of the protrusion 13 in the absence of the voltage application, the twisting directions thereof are also opposite to each other with the voltage applied. Therefore, two side regions of the protrusion 13 where the twisting directions of the liquid crystal molecules are opposite to each other are present so that the optical characteristics of the two regions are compensated, resulting in a wide viewing angle. In addition, disclination regions where the orientation directions of the liquid crystal molecules 30 are disorderly altered are focused at the regions of the protrusions 13 and 23 so that a black matrix for shielding the disclination regions can be formed in a predetermined manner.

However, in order to fabricate the above-described liquid crystal displays, additional processes for forming the protrusions 13 and 14 or the opening portions 1



and 2 must be performed.

On the one hand, in the case of the liquid crystal display shown in Figs. 1A and 1B, a wet etching process for forming the opening portion 2 at the ITO-based common electrode 21 of the top substrate 20 should be provided. Furthermore, in order to prevent the color filter from being contaminated or damaged due to the etching solution, a protective layer of organic or inorganic materials should be coated onto the color filter before the ITO processing.

On the other hand, in the case of the liquid crystal display shown in Figs. 2A and 2B, before the formation of the protrusions 13 and 23, separate organic layers should be coated onto the pixel electrode 12 and the common electrode 22, and etched.

#### **[TECHNICAL TASK OF THE INVENTION]**

It is an object of the present invention to provide a vertical alignment liquid crystal display which has a multi-domain pixel structure.

It is another object of the present invention to provide a vertical alignment liquid crystal display with a multi-domain pixel structure which can be fabricated in a simplified manner.

#### **[CONFIGURATION AND OPERATION of the invention]**

These and other objects may be achieved by a liquid crystal display with at least one pair of first and second protrusions and pixel electrodes having an opening pattern exposing the first protrusion while covering the second protrusion.

According to one aspect of the present invention, the liquid crystal display includes a first substrate having a plurality of pixel areas. At least one pair of first and second protrusions formed parallel to each other are provided at each pixel area. A pixel electrode is formed at each pixel area. The pixel electrode has an opening

pattern exposing the first protrusion while covering the second protrusion. A second substrate faces the first substrate, and a common electrode is formed at the second substrate. A negative dielectric anisotropy liquid crystal is sandwiched between the first and second substrates. A first vertical alignment film is coated on the common electrode, and a second vertical alignment film is coated on the pixel electrode and the first protrusion.

The first and second protrusions may be formed parallel to each other.

The first and second protrusions may have a shape of column having triangle cross section.

The liquid crystal display may further comprise a thin film transistor formed at each pixel area, the thin film transistor comprising a gate electrode, a gate insulating layer formed on the gate electrode, a semiconductor pattern formed on the gate insulating layer over the gate electrode, and source and drain electrodes overlapped with side edges of the semiconductor pattern; and a protective layer covering the thin film transistor.

The first and second protrusions are formed with the same material as at least one of the gate insulating layer, the semiconductor pattern or the protective layer.

The pixel electrode and the common electrode may be formed with indium tin oxide or indium zinc oxide.

Preferred embodiments of this invention will be explained with reference to the accompanying drawings.

Fig. 3 is a cross sectional view of a liquid crystal display with a TFT array substrate and a color filter substrate according to a preferred embodiment of the present

invention.

The TFT array substrate 10 has a plurality of pixel areas at which a gate electrode, a gate insulating layer, a semiconductor pattern, and source and drain electrodes are sequentially formed. As shown in Fig. 3, a pair of pyramid-shaped protrusions 11 and 12 are formed at each pixel area. The protrusions 11 and 12 may be formed with the same material as the semiconductor pattern, the gate insulating layer, or a protective layer covering the source and drain electrodes.

A pixel electrode 13 covers the protrusion 12 and the TFT array substrate 10, and it has an opening pattern 5 exposing the protrusion 11. A first vertical alignment film 14 is coated on the pixel electrode 13 and the exposed protrusion 11 to vertically align negative dielectric anisotropy liquid crystal molecules 31 and 32.

In addition, the color filter substrate 20 is sequentially overlaid with a transparent common electrode 21 and a second vertical alignment film 22 such that they face the TFT array substrate 10.

The liquid crystal molecules 31 and 32 are injected into the gap between the TFT array substrate 10 and the color filter substrate 20. Most of the liquid crystal molecules 31 are oriented perpendicularly to the substrates 10 and 20 due to the vertical alignment films 21 and 22, whereas the liquid crystal molecules 32 adjacent to the protrusions 11 and 12 are tilted with respect to the substrates 10 and 20, at predetermined angles.

Fig. 4 illustrates the orientation states of the liquid crystal molecules under the application of voltage.

As shown in Fig. 4, when voltage is applied to the pixel electrode 13 of the TFT array substrate 10 and the common electrode 21 of the color filter substrate 20, a

vertical electric field is formed at most of the pixel area, excepting some regions. That is, a hill-shaped electric field E1 is formed at the pixel regions at either side of the opening pattern 5 of the pixel electrode 13 exposing the protrusion 11. The hill-shaped electric field E1 begins from the boundary of the opening pattern 5 and is focused onto the common electrode 21 of the color filter substrate 20. Furthermore, a valley-shaped electric field E2 is formed at the side pixel regions of the protrusion 12 covered by the pixel electrode 13. The valley-shaped electric field E2 begins from the center of the protrusion 12, and spreads over the common electrode 21.

The electric fields E1 and E2 are symmetrically formed with respect to each center of the opening pattern 5 and the protrusion 12, making the liquid crystal molecules 33 at the side regions thereof to be tilted in opposite directions. In this way, the optical characteristics of the liquid crystal molecules 33 at the side pixel regions related to the opening pattern 5 or the protrusion 12 are compensated, resulting in wide viewing angle.

Disclination areas D1 and D2 where liquid crystal molecules 34 are disorderly oriented are present at the borderline pixel regions between the side pixel regions. Such disclination areas appear to be wider at the borderline pixel region related to the opening pattern 5 than at the borderline pixel region related to the second protrusion 12. However, since the first protrusion 11 is internally formed at the opening pattern 5, the width of the disclination area D1 related to the opening pattern 5 is significantly reduced. The reason is that the orientation direction of the liquid crystal molecules 32 at the opening pattern 5 before the application of voltage stands in the direction of the electric field E1 with a relatively large angle. As the liquid crystal molecules 32 are initially

tilted at a predetermined angle with respect to the substrate 10, the required energy for vertically aligning the liquid crystal molecules 32 with respect to the direction of the electric field E1 is relatively low so that the orientation of most of the liquid crystal molecules 33 can be easily established. Therefore, the relatively wide disclination area related to the opening pattern 5 alone can be narrowed with the addition of the protrusion 11, and focused onto the apex of the protrusion 11 in a stable manner.

The above-described structure of the liquid crystal display may be referred to as the “enhanced vertical alignment (EV) mode.”

In the EV mode liquid crystal display, the TFT array substrate basically has at least two protrusions and a pixel electrode with an opening pattern at each pixel area where one of the protrusions is covered by the pixel electrode and the other protrusion is exposed through the opening pattern. In this structure, the orientation directions of the liquid crystal molecules can be effectively differentiated based on the protrusion and opening patterns, and disclination regions can be reduced in width. Furthermore, as the protrusion pattern can be formed during the TFT formation process by using the TFT formation layers such as the protective layer, the gate insulating layer and the semiconductor layer, and the opening pattern can be formed during the pixel electrode formation process, separate processing steps with additional materials for the pattern formation are not required.

#### **[ADVANTAGE OF THE INVENTION]**

As described above, a new pattern structure capable of effectively dividing the pixel area into multiple domains is formed at one substrate so that the processing steps can be simplified

[CLAIMS]

1. A liquid crystal display comprising:  
a first substrate having a plurality of pixel areas;  
at least one pair of first and second protrusions formed at each pixel area;  
a pixel electrode formed at each pixel area, the pixel electrode having an opening pattern exposing the first protrusion while covering the second protrusion;  
a second substrate facing the first substrate; and  
a common electrode formed at the second substrate.
2. The liquid crystal display of claim 1 further comprising a negative dielectric anisotropy liquid crystal sandwiched between the first and second substrates.
3. The liquid crystal display of claim 2 further comprising a first vertical alignment film coated on the common electrode, and a second vertical alignment film coated on the pixel electrode and the first protrusion.
4. The liquid crystal display of claim 1 wherein the first and second protrusions are formed parallel to each other.
5. The liquid crystal display of claim 4, the first and second protrusions may have a shape of column having triangle cross section.
6. The liquid crystal display of claim 1 further comprising:  
a thin film transistor formed at each pixel area, the thin film transistor comprising a gate electrode, a gate insulating layer formed on the gate electrode, a semiconductor pattern formed on the gate insulating layer over the gate electrode, and source and drain electrodes overlapped with side edges of the semiconductor pattern; and  
a protective layer covering the thin film transistor.

7. The liquid crystal display of claim 6 wherein the first and second protrusions are formed with the same material as at least one of the gate insulating layer, the semiconductor pattern or the protective layer.

8. The liquid crystal display of claim 1 wherein the pixel electrode is formed with indium tin oxide or indium zinc oxide.

9. The liquid crystal display of claim 1 wherein the common electrode is formed with indium tin oxide or indium zinc oxide.

I, the undersigned, who have prepared English translation which is attached herewith, hereby declare that the aforementioned translation is true and correct translation of officially certified copy of the Korean Patent Application No. 99-26027 filed on June 30, 1999.

This 29<sup>th</sup> day of July, 2004

Translator:

Parkjongha  
PARK, Jong-Ha



**KOREAN INDUSTRIAL PROPERTY OFFICE**

This is to certify that the following application annexed hereto is a true copy from the records of the Korean Industrial Property Office.

**Application Number: Patent Application No. 99-26027**

**Date of Application: June 30, 1999**

**Applicant(s): Samsung Electronics Co., Ltd. (LCD Business)**

**COMMISSIONER**

(Translation)

**APPLICATION FOR PATENT**

**APPLICANT:** Samsung Electronics Co., Ltd. (LCD Business)  
416, Maetan-dong, Paldal-ku, Suwon-city,  
Kyungki-do, Korea

**ATTORNEYS:** Won-Ho KIM, Won-Kun KIM

**INVENTORS :** 1) SONG, Jang-Kun  
of Samik Apt. 5-201, Seocho 4-dong,  
Seocho-ku, Seoul, Korea

**TITLE OF INVENTION:** Vertically-Alligned Liquid Crystal  
Display and Manufacturing Method thereof

Submitted herewith is/are an application identified above pursuant to  
Article 42 of the Patent Act.

This 30<sup>th</sup> day of June, 1999

Patent Attorneys: Won-Ho KIM  
Won-Kun KIM

To the Commissioner of  
the Korean Industrial Property Office

Attachment: 1. Abstract, specification (and drawing) - one copy each

## **[ABSTRACT OF THE DISCLOSURE]**

### **[ABSTRACT]**

A liquid crystal display is manufactured by forming a gate line assembly on a first substrate; depositing a gate insulating layer on the gate line assembly; forming a semiconductor pattern on the gate insulating layer; forming a data line assembly on the structured first substrate, the data line assembly comprising source and drain electrodes; depositing a protective layer onto the data line assembly, the semiconductor pattern and the gate insulating layer; forming a first protective pattern and a first gate insulating pattern on the data line assembly, the semiconductor pattern and the gate line assembly except some portion of the drain electrode by etching the protective layer and the gate insulating layer, and forming a protrusion pattern at the pixel area, the protrusion pattern being formed with the second protective pattern and the second gate insulating pattern. As described above, a new pattern structure capable of effectively dividing the pixel area into multiple domains is formed at one substrate so that the processing steps can be simplified.

### **[REPRESENTATIVE FIGURE]**

Fig. 6

### **[KEY WORDS]**

vertical alignment, domain division, opening pattern, protrusion

**[SPECIFICATION]**

**[TITLE OF THE INVENTION]**

Vertically Aligned Mode Liquid Crystal Display and Manufacturing Method thereof

**[BRIEF DESCRIPTION OF THE DRAWINGS]**

Figs. 1A and 1B are cross sectional views of a liquid crystal display according to a prior art, illustrating the orientation states of liquid crystal molecules when voltage application is absent and present, respectively;

Figs. 2A and 2B are cross sectional views of a liquid crystal display according to another prior art, illustrating the orientation states of liquid crystal molecules when voltage application is absent and present, respectively

Fig. 3 is a cross sectional view of a liquid crystal display according to an exemplary embodiment of the present invention illustrating the shapes of the electric fields at different domains;

Fig. 4 is a cross sectional view of the liquid crystal display shown in Fig. 3, illustrating the orientation states of the liquid crystal molecules due to the electric fields;

Fig. 5 is a plan view of the liquid crystal display according to an exemplary embodiment of the present invention;

Fig. 6 is a sectional view of the liquid crystal display taken along the VI-VI' line of Fig. 5;

Figs. 7A to 7C are cross sectional views of the liquid crystal display shown in Fig. 6, illustrating the steps of processing a color filter substrate for the liquid crystal display in a sequential manner; and

Figs. 8A to 8F are cross sectional views of the liquid crystal display shown in Fig. 6, illustrating the steps of processing a TFT array substrate for the liquid crystal display

in a sequential manner.

**[DETAILED DESCRIPTION OF THE INVENTION]**

**[OBJECT OF THE INVENTION]**

**[FIELD OF THE INVENTION AND CONVENTIONAL ART IN THE FIELD]**

The present invention relates to a liquid crystal display and, more particularly, to a vertical alignment liquid crystal display which has a structure capable of dividing a pixel area into multiple domains with different orientation directions of liquid crystal molecules.

Generally, liquid crystal displays have a structure where a liquid crystal is sandwiched between two substrates, and an electric field is applied to the liquid crystal to control the amount of light transmission.

In the usual twisted nematic (TN) liquid crystal displays, the liquid crystal molecules injected into the gap between the two substrates are oriented parallel to the substrates, and spirally twisted with a predetermined pitch. The long axis (usually called the "director") of the liquid crystal molecules continuously varies in orientation direction, and the viewing angle characteristics depend upon such orientation directions of the liquid crystal molecules.

However, in the TN liquid crystal display, light is not completely blocked at an off state in the normally black mode so that a poor contrast ratio results. The contrast ratio is altered depending upon the viewing angle, and there is a half tone of brightness difference depending on the viewing angle so that stable picture images cannot be obtained. Furthermore, the picture qualities at side edge portions of the screen are not symmetrical to each other with respect to the middle portion. These all result in poor viewing angle characteristics.

However, the vertical alignment liquid crystal displays where the liquid crystal molecules are vertically aligned in the absence of a voltage but twisted in various directions with the voltage applied exhibit excellence in various aspects, such as contrast ratio and response speed compared to the TN liquid crystal displays. Furthermore, when a compensation film is used to divide the twisting of the liquid crystal molecules in various predetermined directions, a wide viewing angle can be effectively obtained.

Recently, a technique for forming an alignment control member such as a pyramid-shaped protrusion on the substrates, a technique for forming an opening pattern at the transparent electrodes, and a technique for forming a protrusion pattern on one of the substrates while forming an opening pattern at the other substrate have been proposed as methods to control the orientation directions of the liquid crystal molecules. The protrusion or opening pattern is designed to achieve four domain divisions in the orientation direction of the liquid crystal molecules at which the efficiency of light usage becomes highest.

Figs. 1A and 1B are cross sectional views of a liquid crystal display according to a prior art where the orientation states of liquid crystal molecules are illustrated in the absence and presence of the voltage application.

As shown in the drawings, a transparent pixel electrode 11 is formed at a bottom substrate 10, and a first opening portion 1 is formed at the pixel electrode 11. A top substrate 20 facing the bottom substrate 10 is provided with a transparent common electrode 21. A second opening portion 2 is formed at the common electrode 21. The bottom and top substrates 10 and 20 are arranged such that the first opening

portion 1 is displaced with respect to the second opening portion 2. Negative dielectric anisotropy liquid crystal molecules 30 are injected into the gap between the bottom and top substrates 10 and 20.

As shown in Fig. 1A, the liquid crystal molecules 30 are oriented perpendicular to the substrates 10 and 20 in the absence of the voltage application.

As shown in Fig. 1B, when voltage is applied to the pixel electrode 11 and the common electrode 21, most of the regions at the pixel area are under the influence of an electric field normal to the substrates 10 and 20, but the regions adjacent to the opening portions 1 and 2 are under a fringe field beginning from the edges of the opening portions 1 and 2 and focused onto the common electrode 21 and the pixel electrode 11, respectively. As the negative dielectric anisotropy liquid crystal molecules 30 are inclined to orient in a direction normal to that of the electric field, the long axes of the liquid crystal molecules adjacent to the opening portions 1 and 2 are twisted while being tilted with respect to the substrates 10 and 20. In this case, two side regions of either of the opening portions 1 and 2 where the orienting directions of the liquid crystal molecules 30 are opposite to each other are present so that the optical characteristics of the two side regions are compensated, resulting in a wide viewing angle.

Figs. 2A and 2B are cross sectional views of a liquid crystal display according to another prior art where the orientation states of liquid crystal molecules are illustrated in the absence and presence of voltage application.

As shown in Figs. 2A and 2B, a pixel electrode 12 based on a transparent conductive material such as indium tin oxide is formed at a bottom substrate 10, and a

pyramid-shaped first protrusion 13 and a vertical alignment film (not shown) are sequentially formed on the pixel electrode 12. A transparent common electrode 22 is formed at a top substrate 20, and a second pyramid-shaped protrusion 23 and a vertical alignment film (not shown) are sequentially formed at the common electrode 22. Negative dielectric anisotropy liquid crystal molecules 30 are injected into the gap between the vertical alignment films of the bottom and top substrates 10 and 20.

As shown in Fig. 2A, in the absence of voltage application, most of the liquid crystal molecules 30 are oriented perpendicular to the vertical alignment films, but the liquid crystal molecules 30 positioned close to the protrusions 13 and 23 are tilted with respect to the vertical alignment films at predetermined angles.

As shown in Fig. 2B, when voltage is applied to the pixel and common electrodes 12 and 22, the liquid crystal molecules are twisted in a direction parallel to the substrates 10 and 20. As the liquid crystal molecules 30 positioned close to the protrusion 13 are tilted in the opposite directions with respect to the region of the protrusion 13 in the absence of the voltage application, the twisting directions thereof are also opposite to each other with the voltage applied. Therefore, two side regions of the protrusion 13 where the twisting directions of the liquid crystal molecules are opposite to each other are present so that the optical characteristics of the two regions are compensated, resulting in a wide viewing angle.

However, in order to fabricate the above-described liquid crystal displays, additional processes for forming the protrusions 13 and 14 or the opening portions 1 and 2 must be performed.

On the one hand, in the case of the liquid crystal display shown in Figs. 1A and



1B, a wet etching process for forming the opening portion 2 at the ITO-based common electrode 21 of the top substrate 20 should be provided. Furthermore, in order to prevent the color filter from being contaminated or damaged due to the etching solution, a protective layer of organic or inorganic materials should be coated onto the color filter before the ITO processing.

On the other hand, in the case of the liquid crystal display shown in Figs. 2A and 2B, before the formation of the protrusions 13 and 23, separate organic layers should be coated onto the pixel electrode 12 and the common electrode 22, and etched.

Furthermore, misalignment occurring during assembling the lower substrate 10 and the upper substrate 20 may induce problem.

#### **[TECHNICAL TASK OF THE INVENTION]**

It is an object of the present invention to provide a vertical alignment liquid crystal display which has a multi-domain pixel structure.

It is another object of the present invention to provide a vertical alignment liquid crystal display with a multi-domain pixel structure which can be fabricated in a simplified manner.

It is the other object of the present invention to provide a vertical alignment liquid crystal display without problem induced by misalignment.

#### **[CONFIGURATION AND OPERATION of the invention]**

These and other objects may be achieved by manufacturing a liquid crystal display having protrusions and openings on the lower substrate through forming the protrusion along with patterning the gate insulating layer and the protection layer and forming the openings along with forming the pixel electrodes.

A thin film transistor is formed at each pixel area. The thin film transistor

includes a gate electrode, a gate insulating layer formed on the gate electrode, a semiconductor pattern formed on the gate insulating layer over the gate electrode, and source and drain electrodes overlapped with side edges of the semiconductor pattern. A protective layer covers the thin film transistor.

The liquid crystal display may further comprise a negative dielectric anisotropy liquid crystal sandwiched between the first and second substrates.

The liquid crystal display may further comprise vertical alignment films coated on the common electrode and the pixel electrode.

The cross section of the protrusion is shaped as a rectangle.

The first and second protrusions are formed with the same material as at least one of the gate insulating layer, the semiconductor pattern and the protective layer. The pixel electrode and the common electrode are formed with indium tin oxide or indium zinc oxide.

The cross section of the protrusion pattern may be shaped as a rectangle.

The protrusion pattern may comprise an under-layer formed with the same material as the gate insulating pattern, and an over-layer formed with the same material as the protective pattern.

The gate insulating pattern may have the same shape as the protective pattern except some portion under the drain electrode.

The liquid crystal display may further comprise color filters formed at the second substrate while corresponding to the pixel areas of the first substrate, the color filters being positioned between the common electrode and the second substrate; and a light interception layer interposed between the neighboring color filters.

The liquid crystal display may further comprise a negative dielectric anisotropy liquid crystal sandwiched between the first and second substrates.

The liquid crystal display may further comprise vertical alignment films formed on the pixel electrode and the common electrode to vertically align liquid crystal molecules.

The common electrode may be formed with indium tin oxide or indium zinc oxide.

The pixel electrode may be formed with indium tin oxide or indium zinc oxide.

According to another aspect of the present invention, the liquid crystal display includes a first substrate having a plurality of pixel areas, and a plurality of protrusions formed at each pixel area of the first substrate. A pixel electrode covers the protrusions. The pixel electrode has opening portions. The opening portions and the protrusions are formed in parallel. A second substrate faces the first substrate, and a common electrode is formed at the second substrate. A negative dielectric anisotropy liquid crystal is sandwiched between the first and second substrates. Vertical alignment films are coated on the common electrode and the pixel electrode, respectively. The cross section of the protrusion is shaped as a rectangle.

The color filters may be formed on a second substrate; a common electrode may be formed on the color filters through depositing a second transparent conductive layer onto the substrate with the color filters; and the first and second substrates are aligned such that the pixel electrode faces the common electrode.

A liquid crystal is injected into the gap between the first and second substrates.

Preferred embodiments of this invention will be explained with reference to the accompanying drawings.

Fig. 3 is a cross sectional view of a liquid crystal display according to an

exemplary embodiment of the present invention illustrating the shapes of the electric fields at different domains;

As shown in Fig. 3, a protrusion pattern 15 having a rectangular-shaped cross section is formed at the gate insulating layer and the protective layer over the TFT array substrate 10, and a pixel electrode 16 of indium tin oxide (ITO) or indium zinc oxide (IZO) covers the protrusion pattern 15. An opening pattern 3 is formed at the pixel electrode 16 while being alternately arranged with the protrusion patterns 15. At least one protrusion pattern 15 and one opening pattern 30 are provided within each pixel area. The color filter substrate 20 is overlaid with color filters (not shown) and a transparent common electrode 25 covering the color filters such that they face the TFT array substrate.

When voltage is applied to the common electrode 25 and the pixel electrode 16, electric fields  $E$  and equi-potential lines  $E_{eq}$  are formed between the TFT array substrate 10 and the color filter substrate 20. That is, a hill-shaped electric field  $E$  is formed at the opening pattern 3 while beginning from the edge of the opening pattern 3 and focusing onto the common electrode 25 of the color filter substrate 20. A valley-shaped electric field  $E$  is formed at the protrusion pattern 15 while beginning from the center of the protrusion pattern 15 and spreading over the common electrode 25. Therefore, the electric fields  $E$  and the equipotential lines  $E_{eq}$  uniformly appear in a symmetrical manner with respect to the center of the protrusion pattern 15 or the opening pattern 3.

Fig. 4 is a cross sectional view of the liquid crystal display shown in Fig. 3, illustrating the orientation states of the liquid crystal molecules due to the electric fields.

As shown in Fig. 4, the negative dielectric anisotropy liquid crystal molecules 30 injected into the gap between the two substrates 10 and 20 are tilted symmetrical to each other at two side regions of either of the protrusion pattern 15 and the opening pattern 3 because the long axis thereof is inclined to be oriented perpendicular to the electric fields E or parallel to the equipotential lines. Therefore, the optical characteristics of the liquid crystal molecules at the two side regions are compensated, resulting in a wide viewing angle.

Fig. 5 is a plan view of the liquid crystal display according to an exemplary embodiment of the present invention and Fig. 6 is a sectional view of the liquid crystal display taken along the VI-VI' line of Fig. 5;

As shown in the drawings, the TFT array substrate 10 is overlaid with a gate line assembly including gate lines 101 formed in the horizontal direction, and gate electrodes 102 extended from the gate lines 101. A first gate insulating pattern 201 covers the gate line 101 and the gate electrode 102. An amorphous silicon semiconductor pattern 301 is formed on the first gate insulating pattern 201 over the gate electrode 102. A doped amorphous silicon ohmic contact pattern 402 is formed on the semiconductor pattern 301 while being absent over the gate electrode 102. Data lines 501 proceeding in the vertical direction are formed on the first gate insulating pattern 201 such that they cross the gate lines 101. Source electrodes 502 are extended from the data lines 501 while contacting the ohmic contact pattern 402 at one side, and drain electrodes 503 are separately positioned opposite to the source electrodes 502 with respect to the gate electrodes 102 while contacting the ohmic contact pattern 402 at the other side. A first protective pattern 601 covers the first gate

insulating pattern 201, the semiconductor pattern 301, the data lines 501, and source and drain electrodes 502 and 503 over the gate line 101 and the gate electrode 102.

The first protective pattern 601 has substantially the same shape as the first gate insulating pattern 201 except that it is removed over the drain electrode 503. The first protective pattern 601 and the first gate insulating pattern 201 are absent over the pixel area defined by the neighboring gate and data lines 101 and 501.

Meanwhile, a protrusion pattern 15 having one or more protrusions is formed at the pixel area. The protrusion pattern 15 has a double layered structure where a second protective pattern 602 is formed on a second gate insulating pattern 202. The second gate insulating pattern is formed with the same material as the first gate insulating pattern 201, and the second protective pattern 602 is formed with the same material as the first protective pattern 601. The protrusion pattern 15 has a protrusion width of 3-8 $\mu$ m.

In the following preferred embodiments, the pixel area will be considered to have a substantially rectangular shape with first and second long sides, and first and second short sides. It is further assumed that the rectangular-shaped pixel area has an upper region with the first short side, and a lower region with the second short side, and the upper and lower regions are bisected by a center line.

The protrusion pattern 15 is symmetrically formed at the upper and lower pixel regions while proceeding at 45° with respect to the center line. The protrusion pattern 15 includes top, middle and bottom protrusions.

The middle protrusion has a V-shaped base positioned around the center line while facing the first long side of the pixel area. The V-shaped base has a bent portion

on the center line, and two wings symmetrically extended from the bent portion up and downward while being tilted at  $45^\circ$  with respect to the center line. A first limb 151 is horizontally extended from the bent portion of the V-shaped base toward the second long side of the pixel area along the center line, and second limbs vertically extended from the wings of the V-shaped base up and downward along the first long side of the pixel area, respectively.

The top protrusion of the protrusion pattern 15 has a first linear base proceeding parallel to the upper wing of the V-shaped base of the middle protrusion. A first limb 151 is horizontally extended from the top end of the first linear base along the first short side of the pixel area, and a second limb 152 is vertically extended from the bottom end of the first linear base along the second long side of the pixel area.

The bottom protrusion has a second linear base proceeding parallel to the lower wing of the V-shaped base of the middle protrusion. A first limb 151 is horizontally extended from the bottom end of the second linear base along the second short side of the pixel area, and a second limb 152 is vertically extended from the top end of the linear base along the second long side of the pixel area.

Meanwhile, a pixel electrode 16 of ITO or IZO covers the protrusion pattern 15 while contacting the exposed portion of the drain electrode 50. Some portion of the pixel electrode 16 at the pixel area is removed to thereby form an opening pattern 3. The opening pattern 3 is symmetrically formed at the upper and lower pixel regions while proceeding at  $45^\circ$  with respect to the center line. The opening pattern 3 has top, middle and bottom opening portions.

The top opening portion is placed between the bases of the top and middle

protrusions of the protrusion pattern 15 while proceeding parallel thereto. The bottom opening portion is placed between the bases of the middle and bottom protrusions of the protrusion pattern 15 while proceeding parallel thereto. The middle opening portion proceeds from the first long side of the pixel area toward the bent portion of the V-shaped base of the middle protrusion along the center line.

Roughly, the protrusion pattern 15 and the opening pattern 3 are alternately arranged parallel to each other.

A vertical alignment film (not shown) is formed on the pixel electrode 16.

The color filter substrate 20 facing the TFT array substrate 10 has a light interception layer 700 corresponding to the TFT and the gate and data lines 101 and 501 external to the pixel area, and color filters 801 and 802 corresponding to the pixel area. A common electrode 25 of ITO or IZO is formed on the color filters 801 and 802, and a vertical alignment film (not shown) is coated onto the common electrode 25.

In the liquid crystal display structured with the aforementioned protrusion pattern 15 and the opening pattern 3, the orientation directions of the liquid crystal molecules are differentiated at the two side regions of the protrusion pattern 15 or the opening pattern 3. That is, the pixel area is divided into two domains on the basis of the protrusion pattern 15 and the opening pattern 3, respectively. Furthermore, as the portions of the opening and protrusion patterns 3 and 15 at the upper region of the pixel area proceed symmetrical to those at the lower region, the orientation directions of the liquid crystal molecules at the upper region are also symmetrical to those of the liquid crystal molecules at the lower region. Consequently, the pixel area is divided into four domains where the orientation directions of the liquid crystal molecules are



differentiated, and this results in a wide viewing angle.

The protrusion pattern 15 and the opening pattern 3 are not limited to the above shapes, but can be altered in various manners on the condition that the pixel area is divided into four domains based on the orientation directions of the liquid crystal molecules.

As described above, the electric field at the region of the protrusion pattern 15 is relatively wide, whereas the electric field at the region of the opening pattern 3 is relatively narrow because it is focused on the common electrode 25. Therefore, the pixel area can be effectively divided into multiple domains while improving the viewing angle characteristics. Furthermore, as the formation of the opening or protrusion pattern is necessary only on the TFT array substrate side, the performance characteristics of the common electrode 25 of the color filter substrate are not deteriorated, and production efficiency can be enhanced.

Figs. 7A to 7C are cross sectional views of the liquid crystal display shown in Fig. 6, illustrating the steps of processing a color filter substrate for the liquid crystal display in a sequential manner.

As shown in Figs. 7A to 7C, a matrix type light interception layer 700 is formed on the color filter substrate 20 to shield the periphery of the pixel area, and color filters 801 and 802 are formed at the pixel area where the light interception layer is absent. Thereafter, an ITO or IZO film is deposited onto the substrate 20 to form a common electrode 25. A vertical alignment film (not shown) is coated onto the common electrode 20 to thereby complete the color filter substrate.

Figs. 8A to 8F are cross sectional views of the liquid crystal display shown in Fig.

6, illustrating the steps of processing a TFT array substrate for the liquid crystal display in a sequential manner.

As shown in Fig. 8A, a gate line assembly including gate lines 101 and gate electrodes 102 is formed on the substrate 10, and a gate insulating layer 200 is then formed on the gate line assembly.

Thereafter, as shown in Fig. 8B, an amorphous silicon semiconductor layer and a doped amorphous silicon ohmic contact layer are sequentially deposited onto the substrate 10, and etched together to thereby form an ohmic contact pattern 401 and a semiconductor pattern 301.

As shown in Fig. 8C, a data line assembly including data lines 501, and source and drain electrodes 502 and 503 are formed on the structured substrate 10, and the ohmic contact pattern 401 is etched by using the source and drain electrodes 502 and 503 as a mask.

As shown in Fig. 8D, a protective layer 600 is deposited onto the structured substrate 10.

Thereafter, as shown in Fig. 8E, the protective layer 600 and the underlying gate insulating layer 200 are etched to thereby form a first protective pattern 601 and a gate insulating pattern 201 over the TFT, the gate lines 101 and the data lines 601 external to the pixel area, and a protrusion pattern 15 at the pixel area. The protrusion pattern 15 is formed with the second protective pattern 602 and the second gate insulating pattern 202. Furthermore, in this step, the protective layer 600 over the drain electrode 503 is removed to partially expose the drain electrode 503 to the outside.

The layered structure of the protrusion pattern 15 may be altered by applying

different formation techniques. For instance, in the case when the TFT array substrate is fabricated through four mask processes, the gate insulating layer, the ohmic contact layer, the semiconductor layer and the metal layer for the data line assembly are etched together to thereby form a data line, a semiconductor pattern and an ohmic contact pattern. In this step, the protrusion pattern may be formed with the metal layer for the data line assembly, the semiconductor layer and the ohmic contact layer.

As shown in Fig. 8F, a transparent conductive layer of ITO or IZO is deposited onto the substrate 10, and etched to thereby form a pixel electrode 16 at each pixel area, and an opening pattern 3. The pixel electrode 16 contacts the exposed portion of the drain electrode 503, and the opening pattern 3 is positioned within the pixel electrode 16 at the pixel area.

A vertical alignment film (not shown) is coated onto the pixel electrode 16 with the opening pattern 3 to thereby complete a TFT array substrate.

The TFT array substrate is then aligned with the color filter substrate such that the pixel electrode 16 of the former faces the common electrode 25 of the latter. The substrates are then combined with each other under the application of sealant, and polarizer films are externally attached to the substrates to thereby complete a liquid crystal display.

In the aforementioned process, as only the TFT array substrate is structured to have the protrusion pattern 15 and the opening pattern 3, the possible misalignment occurring when such patterns are separately formed at the TFT array and the color filter substrates is prevented.

Furthermore, as the protrusion pattern 15 and the opening pattern 3 of the TFT

array substrate are formed during the step of exposing the drain electrode 503 by etching the protective layer 600 and the gate insulating layer 200 and the step of etching the pixel electrode 16, additional processing steps for forming the protrusion pattern 15 and the opening pattern 3 are not required.

In addition, since the common electrode 25 of the color filter substrate does not have any opening pattern, the photolithography process for forming such an opening pattern at the common electrode 25 or the process for forming an overcoat buffer layer for protecting the color filter from the etching solution is not required. In this way, the processing steps can be simplified, and the possible increase in the resistance, overetching or undercut of the common electrode 25 in the presence of an opening pattern can be completely prevented.

#### **[ADVANTAGE OF THE INVENTION]**

As described above, a new pattern structure capable of effectively dividing the pixel area into multiple domains is formed at one substrate so that the processing steps can be simplified, and possible non-uniformity in the orientation directions of the liquid crystal molecules at the separate domains due to misalignment of the substrates can be prevented.

[CLAIMs]

1. A liquid crystal display comprising:
  - a first substrate having a plurality of pixel areas;
  - a plurality of protrusions formed at each pixel area of the first substrate;
  - a pixel electrode covering the protrusions, the pixel electrode having opening portions, the opening portions and the protrusions formed in parallel;
  - a second substrate facing the first substrate; and
  - a common electrode formed at the second substrate.
2. The liquid crystal display of claim 1 further comprising a negative dielectric anisotropy liquid crystal sandwiched between the first and second substrates.
3. The liquid crystal display of claim 3 further comprising vertical alignment films coated on the common electrode and the pixel electrode.
4. The liquid crystal display of claim 1 wherein the cross section of the protrusion is shaped as a rectangle.
5. A liquid crystal display comprising:
  - a first substrate;
  - a gate line assembly formed at the first substrate, the gate line assembly comprising gate lines, with gate electrodes extended from the gate lines;
  - a gate insulating pattern covering the gate lines;
  - a semiconductor pattern formed on the gate insulating pattern over the gate electrodes;
  - a data line assembly formed on the structured substrate, the data line assembly comprising source and drain electrodes overlapped with side edges of the

semiconductor pattern, and data lines connected to the source electrodes such that the data lines cross the gate lines;

a protective pattern covering the data line assembly and the semiconductor pattern except some portion of the drain electrode, the protective pattern being absent at a pixel area defined by the neighboring gate and data lines;

a protrusion pattern formed at the first substrate, the protrusion pattern having at least two protrusions positioned within the pixel area;

a pixel electrode covering the protrusion pattern at the pixel area while contacting the drain electrode, the pixel electrode having an opening pattern, the opening pattern being alternately arranged with the protrusion pattern;

a second substrate facing the first substrate; and

a common electrode formed at the second substrate.

6. The liquid crystal display of claim 5 wherein the cross section of the protrusion pattern is shaped as a rectangle.

7. The liquid crystal display of claim 6 wherein the protrusion pattern comprises an under-layer formed with the same material as the gate insulating pattern, and an over-layer formed with the same material as the protective pattern.

8. The liquid crystal display of claim 5 wherein the gate insulating pattern has the same shape as the protective pattern except some portion under the drain electrode.

9. The liquid crystal display of claim 5 further comprising:

color filters formed at the second substrate while corresponding to the pixel areas of the first substrate, the color filters being positioned between the common electrode

and the second substrate; and

a light interception layer interposed between the neighboring color filters.

10. The liquid crystal display of claim 5 further comprising a negative dielectric anisotropy liquid crystal sandwiched between the first and second substrates.

11. The liquid crystal display of claim 10 further comprising vertical alignment films formed on the pixel electrode and the common electrode to vertically align liquid crystal molecules.

12. The liquid crystal display of claim 5 wherein the common electrode is formed with indium tin oxide or indium zinc oxide.

13. The liquid crystal display of claim 12 wherein the pixel electrode is formed with indium tin oxide or indium zinc oxide.

14. The liquid crystal display of claim 5 further comprising an ohmic contact layer disposed between the semiconductor pattern and the source and drain electrodes.

15. A method of fabricating a liquid crystal display comprising the steps of:  
forming a gate line assembly on a first substrate, the gate line assembly comprising gate lines and gate electrodes;

depositing a gate insulating layer onto the first substrate with the gate line assembly;

forming a semiconductor pattern on the gate insulating layer such that the semiconductor pattern is overlapped with the gate electrodes;

forming a data line assembly on the structured first substrate, the data line assembly comprising source and drain electrodes overlapped with side edges of the semiconductor pattern, and data lines connected to the source electrode while crossing

the gate lines to thereby define pixel areas;

depositing a protective layer onto the data line assembly, the semiconductor pattern and the gate insulating layer;

forming a first protective pattern and a first gate insulating pattern on the data line assembly, the semiconductor pattern and the gate line assembly except some portion of the drain electrode by etching the protective layer and the gate insulating layer, and forming a protrusion pattern at the pixel area, the protrusion pattern being formed with the second protective pattern and the second gate insulating pattern;

depositing a first transparent conductive layer onto the structured first substrate;  
and

forming a pixel electrode at the pixel area while forming an opening pattern within the pixel electrode by etching the first transparent conductive layer such that the pixel electrode covers the protrusion pattern while contacting the drain electrode.

16. The method of claim 15 further comprising the steps of:

forming color filters at a second substrate;

forming a common electrode on the color filters through depositing a second transparent conductive layer onto the substrate with the color filters; and

aligning the first and second substrates such that the pixel electrode faces the common electrode.

17. The method of claim 16 further comprising:

coating a first vertical alignment film onto the pixel electrode;

coating a second vertical alignment film onto the common electrode; and

injecting a liquid crystal into the gap between the first and second substrates.



18. The method of claim 17 wherein the liquid crystal has a property of negative dielectric anisotropy.

19. The method of claim 16 wherein the second transparent conductive layer is formed with indium tin oxide or indium zinc oxide.

20. The method of claim 19 wherein the first transparent conductive layer is formed with indium tin oxide or indium zinc oxide.